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16. Abstract

The article discusses a monitor display for automatically regulating steep approaches, advantages of the standard ILS approach profile are presented, and the problem of V/STOL flight guidance is treated with respect to the operational requirements of the ICAO. A steep landing aircraft is proposed to handle these problems; a reduced noise burden for residents of the airport also results from this approach profile.

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A MONITOR DISPLAY FOR AUTOMATICALLY REGULATED STEEP APPROACHES

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1. Introduction /1*

At the present time, international flight guidance has reached an operational technical condition that guarantees the regular disengagement of the IFR-service of conventional aircraft up to weather minima of Category II. The flight service control, procedures belonging to it, and the mechanisms and procedures joined with it in the on-board guidance of the aircraft are limited principally to flight, primarily with linear and only in part curved route-segments of the course and of the vertical profile. In the conditions of today's technology, the final approach follows on good grounds, on the flight path target of the standard ILS, which is linear in the horizontal and vertical planes. This procedure on the one hand is relatively simple to control, as far as flight security operations are concerned; and on the other hand, it gives the pilot of the aircraft an extensive ability to control the progress of the landing approach with respect to flight path target and distance to nominal touchdown point through the radio beacon location on the approach ground line. The advantages of the standard ILS approach profile consist of:

- The considered coordination of the horizontal and vertical components of the given approach profile is easy for the pilot to execute, since the unsegmented completion of the

*Numbers in the margin indicate pagination in the foreign text.

approach with no changes in the course of the target flight path makes no special demands on the spatial imagination.

- The spatially fixed, flat inclined glide path plane leads to a condition desired for conventional flight apparatus, consisting of a narrow coupling in space and time of the approach process, bound together with a stabilized flight condition which comes to an expression in standardized form of values for engine capacity, approach velocity, and velocity of descent.

- The provision of the above for the entire approach in essentially constant parameters relieves the pilot of his activity, so that he can in this case limit his attention to, and concentrate on, disturbances from outside sources.

The ILS approach can be executed by the pilot routinely by use of the standard instrumentation available today. For flight protection, the region closely surrounding the airport can be well displayed by the use of this process, and the coordination of the IFR flight motions presents no special difficulties with regard to time and space separation. One should realize above all at this point, that the ILS approach system is to be broken up simply on the requirements and the operational limitations of the CTOL aircraft presently found in service. In spite of technical possibilities for improvement, it can be considered sufficient for this limited purpose. However, it cannot take care of the specific needs and operational possibilities of the V/STOL aircraft, even from the [illegible] explanations.

2. New Landing Systems and V/STOL Flight Guidance

In the realization of the limitations of the instrument landing system, different agencies have concerned themselves with the definition of a new, non-visual landing system, with the object of producing a conception which suffices as far as possible for all the expected requirements of future flight traffic. Here should be mentioned, by way of an extract, other representative ideas, which the All Weather Operations Panel (AWOP) of the ICAO /2 has published in its 'Operational Requirements for a New Non-Visual Approach and Landing Guidance System' [1]. The ICAO expects an all-weather usefulness from the system specified by it, with a flexibility that is attainable up to now only in visual approaches. This is clearly expressed in the following citation from the 'Operational Requirements':

> 'The guidance system at its highest point of development should place the aircraft in a position to follow curved or segmented approach tracks with the use of suitable on-board equipment, and to deal with the descent on pre-chosen profiles including curved and segmented descent paths.'

The statement used in this connection, 'by the use of suitable on-board equipment,' already indicates that an essential part of the problem of V/STOL flight guidance occurs on board the aircraft, and must be solved by on-board means. This interpretation is made even more precise in the 'Operational Requirements' of the ICAO:

> 'The system information should be provided in such a way that it permits--if it is used to guide an aircraft either manually through reference to flight instruments, or with the assistance of the flight control system--a safe, stable, and definite approach including landing. The properties of the guidance system should furnish information ready for use in connection with on-board displays, which will meet the demands of the transition from instrumented to visual flight.'

From the foregoing quotations the essential viewpoint for judging the operations usefulness of a proposed landing system of this type can be derived:

1. A guidance system in the realm treated here must necessarily be understood as the synthesis of four tightly bound system components:

   - Technical installations on the ground
   - Flight traffic control with the pilot as an influential member of the system
   - On-board technical instrumentation
   - Aircraft director as decision-maker on board

2. The value of the system in service depends decidedly on whether it is successful in using to good advantage the possibilities of three-dimensional path guidance provided by technology with flight apparatus suited to that purpose.

3. New paths are to be opened up for the system interpretation on the ground as well as on board, in order to make curved approach profiles in general practical to carry out.

In the course of this article the on-board system conception will be discussed in depth, and will be illustrated by one realized specific case. To this end, we will proceed from the existence of operational ground installations corresponding to the ICAO requirements, as well as from the availability of suitable V/STOL flight apparatus.

3. Manual and Automatic Flight Guidance

Conventional approaching aircraft already show a trend towards widespread automation of path guidance in their equipment. This development will be continued strongly in the area of V/STOL aircraft--whether in VFR or in the IFR operation. Experience gained in the testing of V/STOL aircraft has shown the necessity of broadly unburdening the pilot from the manual stabilization of his aircraft by suitable regulation and location systems. Just such problems become considerably more important in the field of path guidance when the required target profile exhibits curved and segmented components in azimuth and elevation. In this respect, the target flight path might be thoroughly adapted to the flight mechanical properties and the typical high maneuverability of the V/STOL aircraft. However, the question remains: Which specific information and means of assistance must be at the disposal of the pilot on board, to guarantee a safe execution of the approach, including the landing? Here considerable differences are exhibited, as compared with the ILS approach: /3

A curved approach profile strongly taxes the spatial coordination ability of the pilot. A linear arrangement of space and time during the approach is ordinarily no longer given. The entire path guidance is made dynamic; the target values for thrust, drive, speed of descent, path angle, acceleration for the path as well as the steering course, vary strongly depending upon the approach stage.

To carry out exactly a maneuver such as a profile optimum for noise under visible flight conditions presents, by itself, a flying problem that is already difficult enough; it becomes still considerably more complicated in instrumented flight, and comes as close as possible to the limit of the pilot's capacity. A very promising beginning of relief lies in the automation of of the path guidance, in combination with a decided improvement in the information supply for the pilot. The requirement for automation and improvement of the information supply at the same time might seem contradictory at first, since these two lines of development could end up in basically contrary limiting positions.

Either - Complete automation, even of the decision-making processes and steering functions still reserved for the pilot,

Or - Development of a high-grade refined system for transmitting and displaying the information that permits the pilot to carry out a faultless manual flight mission.

The last-mentioned approach at first glance could find widespread, partly unreflected, acceptance, since it is strongly performance-motivated, and meets halfway the human need for recognition. However, this path must deny all existing experience in the daily routine of flying, where the pilot, with his reliable endurance, is put to work, but not as a man operating at the limits of his capacity. It is much more productive of results to employ the specific abilities of a man where he is undoubtedly superior to the technical systems, namely as a system supervisor and as a decision-maker [2]. This means in a consistent application to automation of the on-board V/STOL flight guidance:

> The pilot should be relieved as far as possible from the actual course guidance by suitable automatic devices, so as to keep free sufficient capacity for his real task, the supervision of the approach and the decision on its continuation.

The question, which occasionally arises in this connection, of a possible conflict of authority between pilot and automatic devices, in actual practice does not come up in this form, since the automatic devices according to the conception put forth here are definitely awarded priority in their specific areas, but the pilot uniquivocally possesses the power of decision in his supervisory function.

4. Information Demands and Information Presentation /4

If the pilot is to safeguard effectively the role assigned to him in the automated on-board guidance system, he must have at his disposal functionally correct indications of the parameters that determine the approach. The typical information demands for the at least partially manually-directed V/STOL approach were summed up by a work group of the AGARD in the report R-594 'V/STOL Displays for Approach and Landing' [3]. Electronic displays were considered therein as the best information presentation on the basis of their multiple employabilities. In the case of the partly automated or automated approach, they allow convenient and safe supervision of the approach, as will be discussed in the plan put forward below, in the form of a monitor display for the automatically regulated steep approach. This plan is supported, as far as the information presentation is concerned, by some of the most important findings of the so-called AGARD report. It could contribute to the strengthening of the necessarily unconditional confidence of the pilot in the function and function capabilities of the complete flight guidance system.

5. The Display

The apparatus normally available on board, for example the attitude director indicator and the horizontal situation indicator, correspond to the demands for observing a straight-line approach at an angle of descent of about 3°. The conditions in a steep approach with variable flight path angles cannot be reproduced sufficiently perspicuously, however, with its help alone.

The needs of the pilot in supervising the automatically regulated approach are already increasing at the beginning of the steep descent because of the relatively large changes of the flight path angle compared to the usual order of magnitude. In this phase, up to now, a graphic display of the completion of the flight, which could strengthen the pilot's confidence in the automatic devices in spite of unusual flight conditions, is lacking. In joint work by the special research area 'Flight Guidance' of the Technical University of Brunswick, and the industry, the development of a program corresponding to this was undertaken. In this study, the indications concerned would not serve for the manual guidance of the aircraft by the pilot, but would serve exclusively for the supervision of the automatically executed approach. To this end, a presentation of the approach profile in side- and ground-plan was chosen, in which the sidewise presentation of the curved approach profile is prominent. For this, an early work which was carried out by the USAF Flight Dynamics Laboratory working jointly with the firm Lear Siegler [4] was drawn on. Here the task consisted of two or three straight segments with different angles of descent. In contrast with the program described here, manually executed steep approaches were assumed in this case. Fig. 1 shows a trial instrument first developed for this purpose. The representation contains as an essential element the indication of the flight path angle and of the longitudinal slope angle in a modified mechanical apparatus. The studies led finally to an electronic indication (Fig. 2), which contains the flight profile with manually selectable segments, the moveable aircraft symbol, and the flight path vector. This indicator was tested in the CH-3E helicopter. It was complemented by a conventional flight director and a horizontal situation indicator. Considering the results obtained in this study, a similar indicator was developed with the help of a computer-controlled display simulator, which was adapted to the special requirements of the automatically regulated approach. Fig. 3

shows the first version. An aircraft symbol is presented which shows the deviation of the aircraft from the guidance beam with respect to the flight profile. The flight path angle is indicated by a rotatable pointer which is guided at the reference point of the aircraft symbol. By this presentation, the pilot's spatial orientation is simplified, and judgments of the regulated flight parameters, as well as of ~~the~~ flight motions, are made possible. In particular, a strong change of the longitudinal slope angle at /5
the beginning of the steep descent will be judged as acceptable by the pilot, as long as the flight path angle remains tangential to the flight profile or close to this. Also, in the case of deviations of the aircraft position from the prescribed flight path caused by wind gusts, the pilot recognizes the orderly work of the automatic installation. The position of the thrust throttle and the size of the position angle, which are likewise supervised by the regulator, are indicated along with the optimum values. Numerical indications of the altitude and the velocity supplement these first projections.

After several studies in the flight simulator and conversations with test pilots, an indicator, which provisionally has attained its final form, was designed by an iterative process, and will be realized as a flight-ready indicating apparatus. From Fig. 4 it can be seen that indications of the aircraft location were arrived at opposite to the original design. These pieces of information, which are in essential components of the ADI (Attitude Director Indicator) and the HSI (Horizontal Situation Indicator), were supplied because they were likewise needed by the pilot for judging the entire situation. The integration of this indication in the presentation was encouraged by a spot still at our disposal. Furthermore, besides this, the indicator field to be supervised on the whole was limited to a minimum in spatial extent. Also, since this additional information serves only the supervision but not the aircraft guidance, the relatively small presentation of the artificial horizon and the localizer indication are permissible.

6. Work in Progress

This indicator design was tested many times in the flight simulator and improved continuously in detail, an enterprise in which both of the previously named companies were deeply involved. At this time, on the basis of the design shown here for the VDO, the Air Flight Apparatus Plant in Frankfurt is preparing a useable apparatus which will shortly be tested in a Do 28 D at the Bodenseewerk Gerätetechnik GmbH Überlingen. In it, the behavior of the pilot in supervising the approach will be especially studied, where the differences in the flight situations from the conventional approach procedures are especially pronounced. The value criteria for guidance techniques will be enlarged for this purpose, through physiological, experimental psychological, and subjective means of evaluation. Parallel to this, in the flight simulator, further studies of effectiveness and interpretation will be carried out on the monitor display, and among other things partial indications for the possibilities of improvement will be studied with the help of the tachistoscope. In this study, special attention will be devoted to those problems that occur from a loss of automatic instruments. In this event, the supervision display becomes a flight guidance display, through which a correspondingly adapted form of the display is necessary. In this case, however, a complete new indicator symbolism should be avoided, and a much more continuous transition should be sought, in order to prevent as much as possible an additional burdening of the pilot through the change in indications. The indication of the flight location, which is little used during the supervisory phase, will come to have much more importance in this case. It will have to be supplemented by a flight director while the indication of the vertical flight profile stays in the background, or can be completely excluded. The possibilities of the electronic image display are advantageously brought into use and offer presentation and changeover possibilities which could hardly be realized in similar form with mechanical apparatus.

7. Summary

The advantages of the steep landing aircraft derive, among other things, from the reduced noise burden for the residents of the region of the takeoff or landing place. Regulators arrived at by radio aids for automatic guidance of an aircraft on a steep approach profile, that can be also multiply-curved through flight and radio technical capabilities, were developed in studies by the industry. The function of the pilot in these is essentially supervisory, and can be made easier for him by new types of indicators. Since the spatial relations between aircraft location and flight profile to be maintained in the case of steep approaches with curved segments have not been perspicuously presented on instruments up to this point, a supervisory display was designed, building on earlier work in other directions. This display, which shows a side view of the curved approach profile with a moveable aircraft symbol and a rotatable flight path vector as primary indications, was studied in the flight simulator, and was improved in several successive steps. A flight test, as well as further studies on the operational uses of the apparatus, is in preparation. The studies and commonly derived results obtained in the course of work up to this point, have confirmed throughout the usefulness of an enterprise of the DFVLR and the Special Research Area Flight Guidance of the Technical University of Brunswick on the one side, and the named industry representatives on the other.

8. Literature

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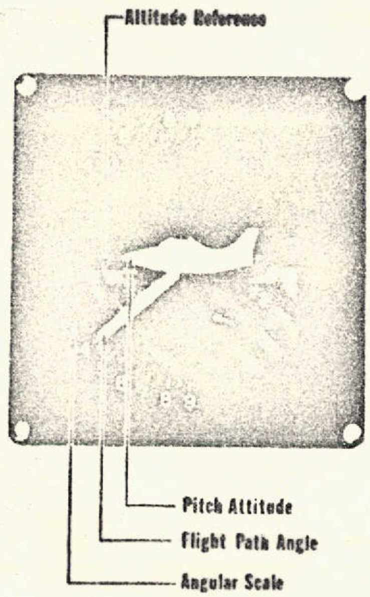

Fig. 1. Mechanical Flight Indicator
(USAF Flight Dynamics Laboratory, 1955)

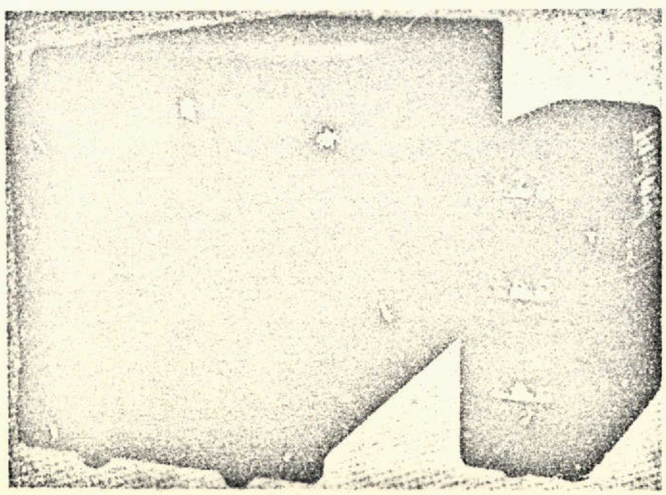

Fig. 2. Electronic Flight Profile Indicating Apparatus
(USAF Flight Dynamics Laboratory - Lear Siegler, 1968)

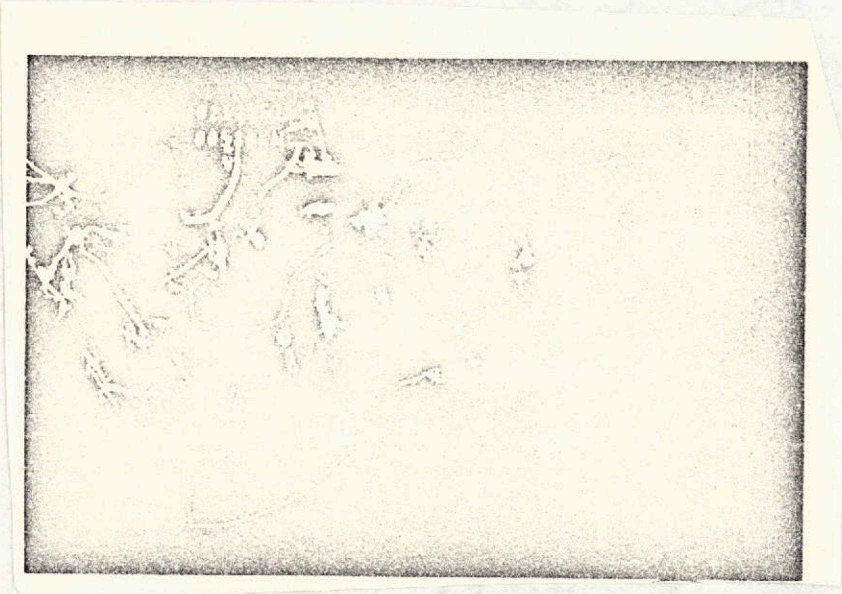

Fig. 3. Electronic Flight Path Indication
(DFVLR, 1. Entwurf 1971)

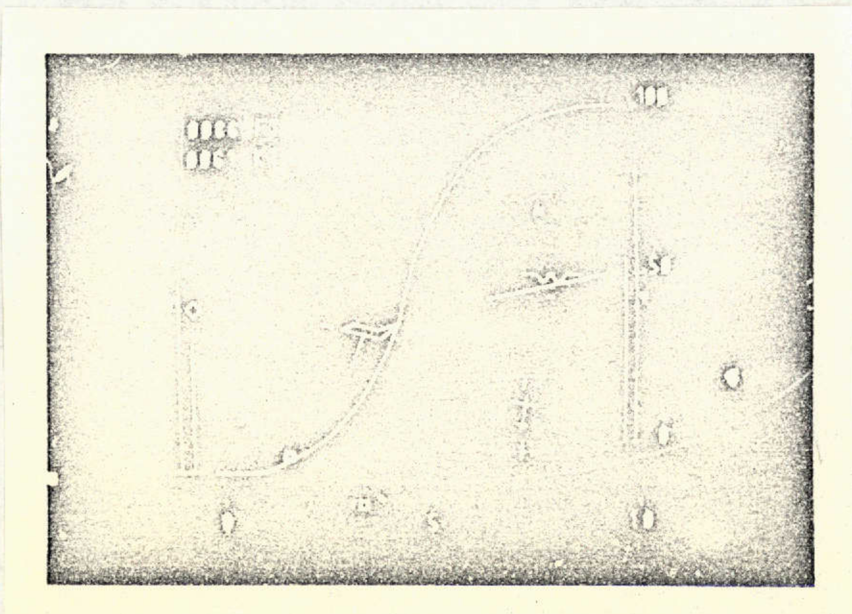

Fig. 4. Electronic Display for Steep Landing
(DFVLR - BGT - VDO, 1972)